A NAVAL POSTGRADUATE DENTAL SCHOOL ANALYSIS OF INITIAL ENDODONTIC TREATMENT

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CERTIFICATE OF APPROVAL

MASTER'S THESIS

This is to certify that the Master's thesis of

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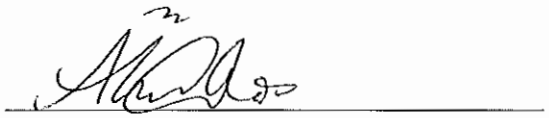

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ABSTRACT

A NAVAL POSTGRADUATE DENTAL SCHOOL ANALYSIS OF INITIAL ENDODONTIC TREATMENT

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Introduction: Initial non-surgical endodontic treatment is associated with high healing rates and clinical success. The literature contains numerous studies that examine the outcomes of initial endodontic treatment. Multiple patient and treatment variables have been reported to affect endodontic outcomes. **Purpose:** The purpose of this retrospective study was to evaluate the outcomes of initial endodontic treatment performed by U.S. Navy endodontists and endodontic residents. A secondary analysis of covariate factors was performed to determine the effect on endodontic outcomes. **Methods:** Subjects that received initial NSRCT by Navy endodontists or endodontic residents and met the inclusion criteria were asked to enroll at the 1 year follow-up examination. Clinical and radiographic data were obtained retrospectively from the initial NSRCT and during the follow-up examination. Clinical and radiographic Pre-treatment, inter-appointment, and follow-up examination data were analyzed using Fisher's Exact test and odds ratios to determine the healed rate as well as the influence of covariate factors on endodontic outcomes. A total of 600 subjects will be enrolled in this study. **Results:** This interim analysis evaluated 390 subjects. The healed rate was determined to be 62.6%. Healed was defined as the absence of a radiographic lesion and no clinical symptoms. The 93% functional rate was defined as the absence of clinical symptoms. Further analysis demonstrated a negative effect on endodontic outcomes for those subjects presenting with a diagnosis of pulp necrosis, pre-operative sinus tract, periapical lesion, a lesion 4mm or larger in diameter, and not using EDTA as an irrigant during the endodontic therapy. **Conclusion:** Interim analysis of initial NSRCT indicated a healed rate of 62.6% with a functional rate of 93%. Multiple covariate factors were determined to affect endodontic outcomes.

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I. INTRODUCTION AND REVIEW OF THE LITERATURE

The criteria for healing in endodontic literature has been measured in various ways. The first guidelines were developed by Strindberg in 1956, in which clinical and radiographic success and failure were discussed. Clinical success was defined as the patient displaying no symptoms and failure was defined as the patient displaying any symptoms. Radiographic success was defined as the radiograph displaying normal contours, width, and structure of the periodontal margin of the endodontically treated tooth (Strindberg, 1956). In 1986, Orstavik *et al* created a scoring system for the radiographic assessment of apical periodontitis, called the periapical index (PAI). In this system, Orstavik *et al* used an ordinal scale of 5 scores ranging from 1 to 5, in which a score of 1 indicated no apical destruction of bone, a score of 2 indicated unlikely apical destruction of bone, a score of 3 indicated an uncertain diagnosis, a score of 4 indicated likely apical destruction of bone, and a score of 5 indicated definite apical destruction (Orstavik, 1986). Using this system, scores of 1 and 2 represented health, while scores of 4 and 5 represented non-healed. Outcomes studies have differed on whether they have chosen to omit the scores of 3 or classify them as non-healed.

The healed rates of initial non-surgical root canal therapy (NSRCT) has varied greatly in the literature. Smith *et al* reviewed 821 endodontic treatments completed between 1970 and 1982 with a follow-up of 5 or more years and found an overall success rate of 84.3%. In this study, success was defined by the lack of symptoms clinically and radiographically, the absence of or diminished lesion at the follow-up (Smith, 1993). Ray *et al* conducted a radiographic study of 1010 endodontically treated teeth completed at Temple University School of Dentistry with a minimum of 1 year follow-up and reported that rate for the absence of periradicular inflammation was 61.7% (Ray, 1995).

Peak *et al* investigated the outcome of initial NSRCT completed by Royal Air Force dental practitioners in the United Kingdom. 406 teeth were evaluated with a minimum of a 1 year follow-up. In this study, definite success was defined as the clinical absence of symptoms and complete absence of a lesion at follow-up. Probable success was defined as the clinical absence of symptoms and a diminished lesion at follow-up. The definite success rate was 57%. The overall success rate when combining definite and probable success was 85% (Peak, 2001).

In a retrospective chart review, Doyle *et al* evaluated 196 teeth that had initial NSRCT with a minimum of a 1 year follow-up, and the healed rate was 86%. Healed was defined as the clinical absence of symptoms with PAI scores of 1 and 2. PAI scores of 3, 4, and 5 were classified as non-healed (Doyle, 2007). Imura *et al* evaluated the treatment outcome of 1,376 teeth over a 30 year period that had initial NSRCT by an endodontist in private practice. In this study, there was a minimum follow-up of 18 months and the healed rate was 94%. Healed was defined as the clinical absence of symptoms and the radiographic absence of a radiolucency (Imura, 2007).

Ng *et al* conducted a systematic review of the outcome of initial NSRCT consisting of 61 studies from 1922 to 2002. It was found that the healed rates of treatments with a minimum of 1 year follow-up ranged from 68% to 85%. However, it was concluded that there was great variability in the assessment of teeth at follow-up, including the method for radiographic evaluation, the criteria for radiographic success, length of follow-up, and the unit of measurement (specific roots versus the entire tooth) (Ng, 2007).

In 1993, the Toronto Study Project on initial NSRCT was established to assess the 4 to 6 year outcome of endodontic treatment performed by graduate students at the University of Toronto. This prospective study was a modular project divided into 4 phases. Phase 1 examined recalls between 1993 and 1995. Phase 2 examined recalls between 1996 and 1997. Phase 3 examined recalls between 1998 and 1999. Phase 4 examined recalls between 2000-2001. Each successive phase provided cumulative data. The healed rate was 81% in Phase 1, 87% in Phase 2, 86% in Phase 3, and 88% in Phase 4. The cumulative healed rate was 86%. Healed was defined as the clinical absence of symptoms, except for percussion sensitivity, and PAI scores of 1 and 2. PAI scores of 3, 4, and 5 were classified as non-healed. When diminished radiolucencies were included in the healed rate, it increased to 91%. It was explained that percussion sensitivity was not included as a symptom of non-healing because it is frequently related to traumatic occlusion, food impaction or periodontal disease (Friedman, 2003; Farzaneh, 2004; Marquis, 2006; De Chevigny, 2008).

Ng *et al* conducted a prospective outcomes study on initial NSRCT on 702 teeth and 534 subjects completed by endodontic postgraduate students with a 2 to 4 year follow-up. Strict criteria of healing was defined as the absence of clinical symptoms and radiographically, the absence of a lesion, and the presence of a normal periodontal ligament (PDL) space. Loose criteria of healing included diminished radiolucencies in addition to the strict criteria guidelines. The healed rate using strict criteria was 82.8% and 89.1% using loose criteria. Additionally, of the 277 teeth with pre-operative lesions, 71.9% healed completely after 1 year, and an additional 19.4% healed after 2 years (Ng, 2011).

Another measurement of endodontic outcomes is functional or clinical success. This is defined by teeth that are clinically asymptomatic regardless of whether there is a radiographic lesion present. The Toronto studies on initial NSRCT reported a functional success rate of 95%; however, percussion sensitivity was not considered a symptom (De Chevigny, 2008). Ng reported a functional success rate of 95.4% (Ng, 2011).

The most lenient endodontic outcomes measures is survivability, defined as the retention of the tooth in the mouth at follow-up, regardless of symptoms or radiographic appearance. Salehrabi *et al* conducted a retrospective survivability study of initial NSRCT in 1,462,936 teeth from over 14 million patients over an 8 year period in a population of patients throughout the United States. Information was gathered from the Delta Dental Insurance company. In total, the survivability was 97.1%. The survivability for anterior teeth, premolars, and molars were

97.43%, 97.32%, and 96.89% respectively. Of the teeth extracted, 85% did not have a full cuspal coverage restoration (Salehrabi, 2004). Ng *et al* conducted a systematic review on tooth survival following NSRCT. Articles selected had a sample size larger than 30 teeth and had at least a 6 month post-operative review. 14 studies were included in the systematic review. It was reported that the survivability of teeth over 2 to 10 years ranged between 86% and 93%. It was concluded that a crown restoration after NSRCT, the tooth having both mesial and distal proximal contacts, the tooth not functioning as an abutment for removable or fixed prosthesis, and non-molar teeth were found to significantly increase survivability (Ng, 2010).

The majority of endodontic outcomes study have been retrospective. One of the greatest challenges in prospective outcomes study is achieving a high follow-up rate, as the existing prospective outcomes study follow-up rates have greatly varied. DeChevigny *et al* reported a follow-up rate of 32% (De Chevigny, 2008). Chong *et al* reported a follow-up rate of 47% (Chong 2003). Ng *et al* reported a follow-up rate of 76% (Ng, 2011).

Different covariate factors have been shown to effect the outcome of endodontic therapy. With regards to pre-existing conditions of the patient, several studies have demonstrated the influence of factors such as diabetes, smoking, and heart disease on the outcome of root canal therapy. In regards to diabetes, Fouad *et al* noted in cases with a pre-operative lesion, a patient having a history of diabetes was associated with a less successful outcome (Fouad, 2003). Wang *et al* reported that diabetes was a significant risk factor for tooth extraction after NSRCT (Wang, 2011). Sanchez-Dominguez *et al* showed that poorly controlled diabetics with a HbA1c greater than 6.5 were associated with a worse periapical status compared to well-controlled diabetics (HbA1c lesser than 6.5) (Sanchez-Dominguez, 2015). Conversely, studies by Doyle *et al* and Lopez-Lopez *et al* demonstrated that diabetes did not significantly affect outcomes (Doyle, 2007; Lopez-Lopez, 2012)

In regards to smoking, Doyle *et al* found that smoking was significantly associated with decreased outcomes of initial NSRCT (Doyle, 2007). Studies by Kirkevang *et al* and Lopez-Lopez *et al* found that smoking was strongly associated with the presence of radiographic lesions. (Kirkevang, 2007; Lopez-Lopez, 2012). Conversely, Duncan *et al* conducted a literature review on the association between smoking and endodontic disease and the prognosis of endodontically treated teeth, and it was not able to be shown that smoking had an effect on the prognosis of initial NSRCT. However, it was noted that there could be potential surgical complications on endodontic surgery. (Duncan, 2006).

Caplan *et al* conducted a cross-sectional study evaluating history of NSRCT and coronary heart disease (CHD). In this study, when patients were younger than 40 years, the incident lesions of endodontic origin were significantly associated with the time of CHD diagnosis (Caplan, 2006). Furthermore, Wang *et al* showed that hypertension and coronary artery disease were significant risk factors for tooth extraction after NSRCT (Wang, 2011).

The pre-operative and peri-operative status of the tooth has been shown to affect endodontic outcomes. In regards to tooth type, the Toronto studies on initial NSRCT demonstrated that single rooted teeth was a significant predictor of healing (De Chevigny, 2008). Peak *et al* found that maxillary anterior teeth had a better healed rate than other tooth types (Peak, 2001). Conversely, Cotton *et al* showed that tooth type had no effect (Cotton, 2008).

Several studies have evaluated the effect of pulp status on outcomes. Kojima *et al* conducted a meta-analysis to determine the factors that affected endodontic prognosis and it was concluded there was a significant difference in healed rates of vital versus non-vital pulps (82.8% versus 78.9%) (Kojima, 2004). Cotton *et al* also showed that vital pulps were a significant predictor of better outcomes (Cotton, 2008). Conversely, Imura *et al* found that pulp status was not a predictor of healing in initial NSRCT. However, it was significant in NSRCT re-treatments (Imura, 2007).

The presence of a pre-operative lesion has been shown to be one of the greatest predictors on non-healing in endodontic outcomes literature. This association was reported in studies by Imura *et al*, the Toronto studies on initial NSRCT, Santos *et al*, and Ng *et al* (Imura, 2007; De Chevigny, 2008; Santos, 2010; Ng, 2011).

Regarding obturation quality and length, Peak *et al* found that root fillings that were within 2 mm of the radiographic apex had a better success rate (Peak, 2001). Ng *et al* found that the absence of root-filling extrusion was found to significantly improve healing (Ng, 2011). Conversely, the Toronto studies found obturation quality and length had no effect (De Chevigny, 2008).

The choice of whether to do root canal therapy in single or multi-visits has been disputable. When completed in multiple visits, an inter-appointment medicament such as calcium hydroxide is often placed in the prepared canals in between appointments in order to reduce bacteria. The advantages of single visit endodontics include cost-effectiveness and less time spent. Several studies have evaluated the effect of single versus multiple visits on the outcome of NSRCT. In general, there has been no significant difference in healing in single and multiple visit root canal treatments. Oliet conducted a clinical study comparing 264 single visit cases and 123 multiple visit cases, and no significant difference in healing was found (Oliet,1983). Sathorn *et al* completed a systematic review and meta-analysis on the effectiveness of single- versus multiple-visit endodontic treatment of teeth with apical periodontitis. Single-visit root canal treatment appeared to be slightly more effective than multiple visits, but the difference was not statistically significant (Sathorn, 2005). Penesis *et al* conducted a randomized controlled clinical trial to compare radiographic evidence of periapical healing after root canal therapy completed in one visit versus two visits with an interim calcium hydroxide/chlorhexidine paste dressing. Sixty-three subjects were evaluated, and no significant difference in healing was noted in the 2 groups (Penesis, 2008). In 2011, Su *et al* conducted a systematic review to compare the healing rate and post-obturation pain of single versus multi-visit root canal

treatment for teeth with infected root canals. 10 randomized clinical trials were included in this review. No significant difference in healing was noted in the 2 groups (Su, 2011).

During root canal therapy, procedural complications, such as fractured instruments occasionally occurs. Various studies have compared the outcomes of teeth with NSRCT that have retained fractured instruments compared to those without. Crump *et al* evaluated the relationship of broken instruments in NSRCT teeth and endodontic case prognosis. 178 cases with retained broken instruments were compared to 400 cases without. No statistically significant difference in healing between the 2 groups was noted (Crump, 1970). Spili *et al* conducted a retrospective survey of 8460 NSRCT teeth (primary & retreatment) over 13.5 years to determine the frequency of retained fractured endodontic instruments and to assess its influence on healing. Overall healing rates were 91.8% for cases with a fractured instrument and 94.5% for the matched controls, with no statistically significant difference between the 2 groups (Spili, 2005). Panitvisai *et al* conducted a systematic review and meta-analysis on the impact of a retained instrument on the outcome of endodontic therapy. Two case-control studies were identified, consisting of 199 cases. It was determined that a retained fragment did not significantly influence healing (Pantivisai, 2010). Conversely, the Toronto studies found that the absence of intra-operative complications was a significant predictor in better outcome in initial NSRCT (De Chevigny, 2008).

Several studies have compared the importance of the quality of the root canal filling versus the quality of the coronal restoration to see which has a greater effect on the periapical status. There have been varying results in the literature. Ray *et al* reported that the quality of the restoration played a greater role compared to the quality of the root canal filling in the likelihood of periapical inflammation (Ray, 1995). Conversely, Tronstad *et al* found the opposite to be true, with the quality of the endodontic treatment playing a greater role (Tronstad, 2000). Gillen conducted a systematic review and meta-analysis on the impact of the quality of coronal restoration versus the quality of root canal fillings on success of root canal treatment. A total of 9 articles were included in the study, and it was concluded that neither factor was more significant than the other concerning the healing of apical periodontitis (Gillen, 2011). All 3 studies agreed that a high quality restoration and NSRCT gave the best result.

No previous study has evaluated the outcome of root canal treatments in a U.S military population. The primary purpose of this retrospective study was to evaluate the outcome of initial non-surgical root canal treatment performed by U.S. Navy Endodontists and residents. A secondary purpose was to report factors that affect the outcome of initial non-surgical root canal treatment.

II. MATERIALS AND METHODS

The materials and methods are described in the Walter Reed National Military Medical Center IRB approved protocol (IRBNet# 352272):

Inclusion Criteria: Adults (18 years or older) who received initial non-surgical orthograde endodontic treatment provided exclusively by an endodontic resident at NPDS or a Navy Endodontist. Treatment must have been completed in at least the twelfth month prior to a follow-up examination and a radiograph, taken at the final obturation appointment, must have been available for consideration as a study participant.

Exclusion Criteria: Patients whose record did not include a final treatment radiograph or whose treatment was completed less than the 12^{th} month prior to follow-up examination were excluded. Also excluded were patients who received non-surgical re-treatment, surgical treatment, or canal obturation using Resilon, carrier-based, silver points or a paste fill technique. Additionally, if any portion of the treatment was performed by any provider who was not a Navy endodontist or Navy endodontic resident, the patient was excluded.

Selection of Subjects: Study subjects were recruited from patients that were previously treated by residents at the NPDS Endodontic Clinic or Navy endodontists. Subjects were recruited from existing logbooks and records of former NPDS residents and from "walk in" and "sick call" patients reporting to the NPDS Endodontic Clinic for evaluation and/or treatment of a tooth.

Eligible patients were asked if they would like to hear more information about the study during their appointment. If they were interested, they were given the study description and the consent forms by an investigator that was not associated with the treatment of the patient.

Consent Process: To avoid coercion, subjects were allowed to decline participation at any time. Once enrolled, they have the opportunity to withdraw at any time. No matter their decision, the follow-up evaluation was completed. Patient consent was obtained by a Primary or Associate Investigator. Investigators were dressed in clinic attire without nametags to prevent coercion. Once all questions were addressed and answered the consent documents were signed and dated.

Study Design and Methodology: This was designed as an observational study combining clinical data obtained from a follow-up examination and retrospective information gathered from the subject's record.

A power analysis was performed with an estimate of healing based on literature by DeChevigny *et al* (De Chevigny, 2008). The estimated healed rate was 85% with a .03 tolerance margin of error producing a sample size of 545. Factoring in a 10% drop-out rate the subject population was set at 600.

Preoperative, intraoperative treatment and follow-up data were collected. In the event that a subject had multiple treated teeth, each tooth was consented individually. All follow-up evaluations were performed by trained endodontic residents supervised by staff endodontists.

Data Collection: Immediate post-treatment radiographs were collected from the existing record. Preoperative data collected included: date of birth, gender, pulpal and apical diagnosis, presence/absence of symptoms, tooth type (single versus multi-root), and existing medical conditions (smoker, coronary heart disease, diabetes).

Intraoperative treatment data gathered included: single vs. multiple treatment sessions, intracanal irrigants and medications, procedural complications, obturation fill length, periradicular status, and placement of an intra-orifice barrier.

Follow-up data gathered included presence/absence of symptoms, apical diagnosis, presence of coronal restoration, presence of intracanal post, periradicular status, and the length of the follow-up period.

The subject number on the data sheets was used to identify the subject on the master database list to de-identify the subjects.

The periradicular status of both post-treatment and follow-up radiographs was assessed by three calibrated board-certified endodontists. In order to avoid reviewer bias during evaluation of the radiographs, the final treatment radiographs were viewed separately from the follow-up radiographs. Additionally, all radiographs were de-identified by assigning them random numbers of which the reviewers did not know the code. The periapical index (PAI) scoring method was used while viewing the images on either a single clinic light-box or a projector. The endodontists were calibrated using selected radiographs and a PAI standard reference. Evaluators scored the radiographs according to the PAI system as healed (scores 1 and 2), undetermined (score 3), or non-healing (scores of 4 and 5). Each evaluator scored the images independently and the final score was attained via forced-consensus in case of disagreement. In the case of multi-rooted teeth the highest PAI value was registered.

Data Analysis: Once the data were collected, the variables were analyzed using the SPSS program to determine significant effects on treatment outcome. Forty seven variables were evaluated for effect on outcome. Statistical analysis was performed on the data including descriptive analysis, Fisher's Exact test and Odd's Ratios. See Table 1.

Table 1

Statistical Analysis Performed and Variables Evaluated

Analysis	*Variable*
Wilcoxon Rank Sum	Age Pre-op pain Pre-op electronic pulp test value Quantity of irrigant used Time from initial treatment to follow-up
Fisher's Exact Test Odd's Ratio	*Pre-operative variables* Gender Hypertension Smoker Coronary heart disease Diabetes Number of roots Pain Pain location by quadrant Pain location by tooth History of orthodontic treatment History of external resorption History of internal resorption History of bleaching Presence of restoration Open margin on restoration Caries *Intra-operative variables* Electronic apex locator use for length Patency Calcium hydroxide use interappointment Procedural complications EDTA use as irrigant Intraorifice barrier placement Number of treatment sessions *Follow-up variables* Permanent restoration Intracanal post Open margin on restoration Tooth location/type Follow-up time Time from treatment to restoration placement

	Post present Probing depth (maximum) Bleeding on probing Mobility Cold sensitivity Percussion sensitivity Palpation sensitivity Sinus tract Swelling Radiolucency Size of radiolucency Intact lamina dura Pulpal diagnosis

III. RESULTS

Enrollment for this interim analysis included 443 subjects. Fifty-three subjects were excluded due to missing data or not meeting eligibility requirements leaving 390 subjects for descriptive and functional rate analysis. Sixty-one additional subjects were excluded from final analysis due to lack of diagnostic radiographs among those patients lacking symptoms leaving 329 patients for outcome analysis.

230 subjects (70%) were male, 99 subjects (30%) were female. Median age was 47, with a range from 19 – 84 years old. The median follow-up time was 14 months with a range from 11.01 months – 10.3 years. Among the 329 subjects for final outcome analysis, 206 (62.6%) were healed and 123 (37.4%) were non-healed. Five variables were found to significantly affect outcome and are listed in Table 2. 363 teeth (93%) were functional with 27 (7%) non-functional.

Table 2

Variables With Significant Effect On Outcome

Variable	**p-Value**	**Odds Ratio (95% CI)**
Sinus tract	<0.001	12.8
Radiolucency ≥ 4mm	<0.001	6.7
Radiolucency	<0.001	5.1
Non-vital pulp	0.028	2.9
EDTA irrigation	0.018	2.0

IV. DISCUSSION

This retrospective study assessed the outcome of initial NSRCT performed by U.S. Navy Endodontists and residents at the follow-up appointment in the 12th month after treatment or later. The healed rate was 62.6% (206/329). There is a great degree of variability between the outcomes reported in the literature. The reported healed rates range from below 60% to over 90%.

This study had a minimum follow-up time of 11 months and 1 day, and the median follow-up was 14 months. The majority of endodontic outcomes literature has assessed outcomes with greater than 12 month follow-ups. Ng *et al* reported a 82.8% healed rate with a 2 to 4 year follow up (Ng, 2011). The Toronto studies reported an 86% healed rate with a 4 to 6 year follow-up (De Chevigny, 2008). Friedman conducted a review of 50 studies from 1956 to 2002 and found that at the end of 1 year, 90% of teeth that will eventually heal, demonstrate signs of healing. However, complete healing may take 4 to 5 years (Friedman, 2002). Zhang *et al* evaluated the change in size of radiographic lesions between the 1 and 2 year follow-ups, and it was reported that 63% of cases had a significant reduction in size at the 2 year follow-up compared to the 1 year follow-up (Zhang, 2015). Molven *et al* conducted a longitudinal study and found that 6.4% of apical radiolucencies at the 10-17 year follow-up healed at the 20-27 year follow-up (Molven, 2002). Thus, given a longer follow-up time, cases in the non-healed group in this study may eventually heal.

In this study, healed was defined as the complete absence of symptoms (percussion, palpation, and thermal sensitivity) and radiographically having a PAI score of 1 or 2 at the follow-up. Other investigatons, such as the Toronto studies, did not include percussion sensitivity as a symptom of non-healing. Seventeen subjects in this study had PAI scores 1 or 2 and displayed percussion sensitivity with no other symptoms at the follow-up. If these subjects were included as healed, the new healed rate would be 67.8% (223/329). Some studies had more loose criteria for healing where diminished radiolucencies at the follow-up were counted as healed. When complete healing of apical radiolucencies were counted as healed, Peak *et al* had a healed rate of 57%, DeChevigny *et al* had a healed rate of 86%, and Ng *et al* had a healed rate of 82.8%. When diminished follow-up radiolucencies were counted as loose criteria for healing, the healed rates were 85%, 91%, and 87.4%, respectively (Peak, 2001; De Chevigny, 2008; Ng, 2011). In this current study, the healed rate with loose criteria was not evaluated.

The clinical success rate was 93% (363/390). This is comparable to the reported findings of De Chevigny *et al* and Ng *et al* of 95% and 95.4% respectively (De Chevigny, 2008; Ng, 2011). However, the Toronto studies did not include percussion sensitivity as a symptom of non-healing. When excluding percussion sensitivity, the clinical success rate of this study was 97.4% (380/390).

The factors noted to predictors of non-healing were the presence of a pre-operative sinus tract, the presence of a pre-operative apical lesion, as well as size of the lesion, a non-vital pulp, and not using ethylenediaminetetraacetic acid (EDTA) as an irrigant.

The finding of a pre-operative sinus tract as a predictor of non-healing is in agreement with Ng *et al*, but in contrast with Chugal *et al* (Ng, 2011; Chugal 2001). The presence of a pre-operative apical lesion has consistently been shown to be a predictor of non-healing (Imura, 2007; Cotton, 2008; De Chevigny, 2008; Santos 2010; Ng, 2011). In regards to size of a pre-operative apical lesion, several studies found that smaller lesions heal better than larger lesions (Matsumoto, 1987; Chugal 2001; Hoskinson 2002; Ng, 2011). However there is variability on the dichotomization of small and large lesions. This study showed that lesions greater than or equal to 4 mm was a predictor of non-healing. Chugal *et al* and Ng *et al* defined large lesions as greater than 3 mm, and Matsumoto *et al* defined large lesions as greater than 5 mm (Matsumoto, 1987; Chugal 2001; Ng, 2011). Hoskinson *et al* found a 18% decrease for every 1 mm increase in lesion size (Hoskinson, 2002). Concerning pulp status, several studies are in agreement that a necrotic pulp is a predictor of non-healing (Chugal, 2001; Kojima, 2004; Cotton, 2008). However, Imura *et al*, found no difference (Imura, 2007).

The finding of the use of EDTA as a predictor of healing is in contrast with existing endodontic literature. There are currently no in vivo studies that have found that the use of EDTA in initial NSRCT has an impact on endodontic outcomes in permanent teeth. More studies are needed on this variable's impact on healing. Ng *et al* found that the use of EDTA in NSRCT retreatment is a predictor of healing, but no statistical significance was found for initial treatment (Ng, 2011).

IV. CONCLUSIONS

The outcome of initial non-surgical root canal treatment by Navy endodontists and residents was noted to be 62.6% healed rate with a 93% functional/clinical success rate. Factors with a negative impact on outcome included presence of a sinus tract, presence and size of a pre-operative radiographic lesion, non-vital pulp, and not using EDTA as an irrigant during endodontic treatment.

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